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THE USE OF ECONOMIC REASONING IN THE PLANNING
FUNCTION OF COMPREHENSIVE WATER DEVELOPMENT
AND POLLUTION CONTROL PROGRAMS UNDERTAKEN
BY THE PUBLIC HEALTH SERVICE

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THE USE OF ECONOMIC REASONING
IN THE PLANNING FUNCTION OF COMPREHENSIVE WATER DEVELOPMENT
AND POLLUTION CONTROL PROGRAMS UNDERTAKEN BY THE PUBLIC HEALTH SERVICE

by
Kenneth C. Nobe*

The Public Health Service has become a major water resources agency and is therefore deeply involved in Federal river basin planning activities. One of its major roles in this field involves the preparation of comprehensive water development and pollution control programs for major river basin systems throughout the country.

Basic authority for the preparation of these programs stems from Section 2 of the Federal Water Pollution Control Act (P.L. 660, 84th Congress) and the 1961 amendments to the Act.^{1/} The Authority states in part:

"The Secretary, Department of Health, Education, and Welfare, shall after careful investigations and in cooperation with other Federal agencies, with State water pollution control agencies and interstate agencies, and with the municipalities and industries involved, prepare or develop comprehensive programs for eliminating or reducing the pollution of interstate waters and tributaries thereof and improving the sanitary conditions of surface and underground waters. In the development of such comprehensive programs due regard shall be given to the improvements which are necessary to conserve such waters for public water supplies, propagation of fish and aquatic life and wildlife, recreational purposes, and agricultural, industrial, and other legitimate uses."

^{1/} For a more complete discussion of the development of the comprehensive water resource development concept refer to: L. B. Dworsky, "Comprehensive Planning and Water Quality Management - Federal Administration," Public Health Service, Department of Health, Education, and Welfare, paper presented at the Water Quality Conference, Washington State University, Pullman, Wash., Nov. 29, 1960.

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Overall planning activities undertaken under the comprehensive program phase of the Water Pollution Control Act are necessarily long-term in nature. Development of comprehensive plans for all of the major river basins in the country will take a number of years. While work on this long-term project is underway, however, an additional need for comprehensive planning for water quality management has developed in conjunction with the pollution control enforcement activities of the Public Health Service. The comprehensive planning activities carried out in conjunction with the Colorado River Basin Water Quality Control Project, for example, was initiated as a result of such an enforcement action. Now with expanded enforcement coverages written into the 1961 amendments of the Act, additional demands for comprehensive water quality planning may be expected to develop on relatively short notice.

Regardless of whether a specific comprehensive planning effort is undertaken under the authority of Section 2 of the Act or as an outgrowth of an enforcement action, the end result should be the same. The planning effort should produce an overall guide to anticipated long-term water quality management needs to insure an adequate supply of high quality water for optimum economic development within the study area. Such planning efforts require the combined specialities of engineering, chemistry, biology, hydrology, demography, political science and last but not necessarily least, economics.^{1/}

^{1/} It appears worth pointing out, in addition, that personnel proficient in these various specialities should be brought into the planning group at the very outset of a study effort. To delay in adding one of these, say a hydrologist, until a project is a year or two old, is equivalent to a football team going through their preseason practice with one of the guard positions vacant.

The role of economics in developing comprehensive water quality management plans is two-fold in nature. First, economics can provide a portion of the basic data required for planning purposes--this phase we commonly refer to as an economic base study.^{1/} Second, and perhaps of greater importance, economics can provide a means of analysis in the planning phase which explicitly introduces the valuations of the public into the process of designing optimum systems. This paper will be devoted primarily to an examination of the latter.

Dr. Frederic O. Sargent, in discussing public resource development policy, once stated: "In practice, legislatures are probably as efficient in allocating resources in accord with public demands, as markets are in reflecting consumer demands."^{2/} To this I would add: neither the legislature or the market place can do a good job of resolving conflict of goals unless rather extensive knowledge of the effects of specific developments and a view concerning the meaning of "public interest" are arrived at. This is the key to the role of economic reasoning in river basin planning efforts. For the most part, comprehensive planning activities to be undertaken by the Public Health Service will be carried out prior to or during the construction phase of water development projects so consideration of consumer demands for specific degrees of water development are particularly important to this effort.

^{1/} For detailed discussions of selected aspects of economic base studies, refer to a number of the papers included in Proceedings of Water Resources Workshop, Public Health Service, Region VII, Department of Health, Education, and Welfare, Dallas, Texas, May 1961.

^{2/} F. O. Sargent "The Political and Economic Framework of Water Resources Development Research," Journal of Soil and Water Conservation, Vol. 15, No. 4, July 1960, p. 156.

How can economic reasoning help us to take consumer demands into account in this process? It requires an understanding of benefit-cost analysis as used in formulating Federal water resource development projects. This basic concept is founded upon the simple value theory supplied by the field of economics.^{1/}

Federal water resource development efforts are formulated under the general guideline that no separable increment of a project is undertaken unless the tangible benefits exceed its development cost.^{2/} This assumes indirectly of course that benefits are always measurable directly in dollar terms. The thesis of this paper, however, is based on the precept that many of the benefits attributable to water quality management are not directly measurable in these terms. Nevertheless, an attempt will be made to show that economic reasoning can be used in evaluating these benefits in such a manner that water quality management project increments can be incorporated in conventional benefit-cost analysis of Federal water resource development projects. The use of what has been called a constrained objective framework is suggested for this purpose. This concept will be discussed in considerable detail in a later section of this paper.

The simple value theory of the economist provides a number of valuable ideas for evaluating water quality management increments of multi-purpose, multi-unit water resource development projects. From it we

^{1/}For a discussion of the use of the simple value theory in comprehensive planning refer to: A. V. Kneese and K. C. Nobe, "The Role of Economic Evaluation in Regional Planning for Water Resource Development," accepted for publication in the Natural Resource Journal.

^{2/}For a detailed discussion of this concept refer to: A. V. Kneese, Water Resources--Development and Use, Technical Appendix "Benefit-Cost Implications of Welfare Economics," Federal Reserve Bank of Kansas City, December 1959. pp. 59-63.

can borrow the concept of marginal adjustments, the measurement of external opportunity costs and benefits by means of market prices and market imputed demand curves, and can gain an insight into the need for considering the effects of water development and use, which would be external to privately managed units, within the marginal benefit-cost framework. In essence, these "borrowed" concepts imply a public policy which would produce the normative results of competitive markets in situations where a variety of factors prevent efficiently functioning competitive markets from developing.

Some General Problems of Benefit Measurement

What are some of these factors that prevent the development of competitive free markets in the water quality management field? An understanding of these is a prerequisite also to consideration of specific evaluation procedures applicable to water quality increments in multi-purpose multi-unit Federal water development projects. The supply conditions of some of the services provided by these increments are of such a character that if they are provided to one consumer they are automatically provided to others, or costs of limiting access to them by others, are prohibitively high. These instances make the measurement of the benefits extremely difficult under the conventional procedures suggested by benefit-cost analysis.^{1/} With respect to water resources, these can be divided into three categories, each of which contains cases which can contribute benefits to the water quality aspects of development.

^{1/} For a discussion of the procedure suggested to Federal agencies, refer to: Subcommittee on Evaluation Standards, Interagency Committee on Water Resources, Proposed Practices for Economic Analysis of River Basin Projects, Washington, D. C., May 1958.

These are:

1. Where the service is not considered a "public" service but the administrative costs of controlling access are high.

This category is particularly significant in the recreational field. For example, in cases where large acreages are involved, it is difficult to protect a recreational development investment from unauthorized entry except at high cost. As a consequence, private development of recreational property is falling rapidly short of anticipated demand. This has a bearing on benefits attributable to water quality management inasmuch as an estimated 60 percent of present outdoor recreation is water oriented and if additional outlets were provided this ratio would probably increase.^{1/}

2. Where the service is "public" but its value can be deduced from what individuals would be willing to pay if they were rationally attempting to maximize individual benefit.

In water resources development, flood control and flow augmentation for navigation and waste disposal are examples of such services. They become important in water resource development analysis because if they are supplied to one individual or firm in the relevant area, they are automatically supplied to others. Therefore, they become public goods because no market could possibly develop for them and there is no way to supply differing amounts to different individuals. Only to the degree that services of this nature avoid damages, or substitute for other services bargained for in the market place, can values be imputed to them. In such instances this can be done by reasoning about what a rational individual would be willing to pay.

^{1/} Public Roads, Vol. 92, No. 8, August 1961. p. 10.

3. Where the product is a "public" good and its value cannot be imputed by reasoning about rational individual choice.

This is the case where a public good does not result in the avoidance of tangible damages to marketable goods and services or does not substitute for a service of known or discoverable market values. General environmental benefits resulting from flow augmentation for waste dilution, where nuisance conditions would otherwise prevail, is such an instance. This case represents the most difficult valuation problem of all. There is a possibility of exploration of preferences, however, via experiments with costs. This is discussed in a following section in conjunction with the constrained objective function for evaluation of water quality management benefits.

A Closer Look at the Pollution Abatement Evaluation Problem

Ordinarily the entire cost of waste disposal in water courses is imposed on downstream users. Pollution, therefore, presents a classic example of external diseconomies. Consider for a moment, the complexities and distortions which commonly occur in a typical pollution loaded stream. There will usually exist numerous separately managed water supply intakes, sewage outfalls, and publicly and privately used intervening stretches of streams and shoreline.

The pollution caused links between fiscally independent units under unregulated market conditions result in inefficient waste disposal systems, in excessive waste disposal, and in a nonoptimal distribution of social costs. There is furthermore, a bias in favor of water supply treatment and a bias unfavorable to sewage treatment and to supplementary pollution abatement measures such as low flow augmentation. The overall costs of pollution are underestimated by the polluters because the costs fall upon other fiscally

independent units in each case. Therefore, costs are imposed on some economic units, not as a result of their own adverse polluting activities, but as a result of the productive activities of others. It becomes clear that the end result of this kind of situation is a distortion of the optimal allocation of resources.

It should be evident also from this discussion that recognition of waste disposal as a problem of optimal system design extends the water resource planning problem beyond the confines of dams, power plants, and diversion works to the full range of alternative means of reducing all the costs associated with waste disposal. Moreover, one should be able to recognize the relationships of complementarity and substitution that exist between flow augmentation and other aspects of multipurpose, multiunit development such as navigation, irrigation, flood control and hydroelectric power generation. But perhaps it would help to state it even more simply: quantity and quality aspects of water resource development are inseparable components in the evaluation process.

How then does a Federal agency such as the Public Health Service proceed in the development of a comprehensive water supply and pollution control program for a specified river basin? Leonard B. Dworsky has listed the following steps:^{1/}

1. The coordinated collection of all possible facts on the problem or issues.
2. The analysis of such facts in an objective, calm and dispassionate setting.
3. The development of alternative solutions as guides to decision-making bodies in determining courses of action.

^{1/} Leonard B. Dworsky, op cit, p. 10.

4. The appraisal of results in implementing the plan and the initiation of review, modification and updating the plan to meet future developments.

The above step-by-step approach suggested by Mr. Dworsky is deceptively simple. It cannot even be applied, as a matter of fact, without some previous specification of goals and criteria which can guide the data collecting and interpreting process. The actual problems involved in attempting literal maximization of an objective in a practical situation involving water quality management are very difficult indeed. This is particularly true when we presuppose an objective such as "net benefit maximization" or the consistent subobjective of "minimizing the costs directly and indirectly associated with an optimum amount of waste disposal." Costs to be considered in this context include among others, those costs associated with abatement measures, water treatment, damages, and foregone alternatives. Adequate consideration of these in the planning process makes great demands upon data, upon ingenuity to devise improved means of solution, and upon actual computation processes.

The data gathering phase requires a coordinated three-way approach consisting of field investigations, a search of relevant information in published literature, and laboratory analysis.^{1/} This phase is of critical importance because the discovery of data gaps at a later date will seriously hamper the planning process. It requires a judgment concerning the information required and is guided by the selection of evaluation criteria relevant to the objective. Unfortunately, too often planning groups rush headlong into the data gathering phase without clearly stating the objectives of the study at the outset.

^{1/}It should be pointed out that all activities embodied in these phases need not necessarily be carried out by the staff of a single agency--many items of information required can often be obtained from other Federal and State development and research agencies.

The analysis phase can likewise move far into left field if the objectives of the study are not clearly recognized. Ideally, the following items would be taken into consideration in a study proceeding under the subobjective of minimizing the real costs associated with waste disposal:

1. All alternative water uses (present and probable).
2. The effects on quality of these various uses.
3. The losses imposed on other uses by quality deterioration including lost recreational opportunities.
4. Costs of treating industrial and municipal supplies.
5. The value of all relevant water derivative uses.
6. The complementary and substitution relationships between development of the various uses.

In other words, all relevant alternative system designs and operating procedures would have to be considered and a solution derived which simultaneously indicated the optimum combination of system elements and their operating procedures. If this were successfully done, the solution would be "efficient," (in an economic context), maximum benefits would be obtained from the available water resources, and as the latter implies, the real costs associated with waste disposal would be minimized.

If all pollution damages and costs of all abatement measures were measurable in terms of market values, a simple criterion for minimizing the social costs of pollution could be specified. The plan would present

a system which equated the marginal costs of waste disposal in all directions.^{1/} Included in these waste disposal costs would be all manner of waste treatment and water supply treatment costs, methods of conforming waste discharge to streamflow costs, costs of required changes in industrial processes, and pollution damages. If costs were not equated at the margin in the initial analysis, it would be possible to improve the situation by "trading off" in such a manner that the overall costs of waste disposal would be minimized. For example, if the cost of a small increase in residual pollution damages, say corrosion of equipment, was found to be less than that of treatment required to prevent it, overall costs would be reduced by trading the damages for the treatment.

Unfortunately, due to the unique characteristics of water (particularly the probabilistic nature of its hydrology) and the illusiveness of the tangible value determination of water quality improvement increments, the setting up and solving of a maximization problem described above cannot be carried out by considering only information provided by or imputable from the market process. The central challenge in pollution abatement planning is to design a system which takes into consideration nonmarket-type goals but at the same time is efficient with respect to the values measured by

^{1/}For simplicity, it is assumed that the amount of waste produced in the planning area is given. This permits neglect of the difficult issues involved in the distribution of costs. In practice, however, industrial waste generation would not be independent of the way in which costs would be distributed (process product changes and waste recovery are variables, for example). Economic theory suggests that in order to assure that the right amount of waste is produced, costs should be distributed in such a way that the full direct and indirect costs (considering the whole system) be levied on the polluter. The great difficulties involved in approximating this result in practice are not discussed in this paper. It should be clear, however, that not even a suboptimum system can be correctly designed without forecasting the effect of the system and its cost distribution on the amount of waste produced.

the market. While in practice, less than the ideal formulation and solution solving procedure must be accepted, stating the problem in this idealized form does help to make clear the far-reaching way in which economic elements are involved in the design problem. Before a possible approach to project formulation (incorporating the above considerations, but going beyond them) is discussed, the complexities introduced by hydrologic variation and imperfect knowledge in regard to benefit determination are discussed briefly in order to place this proposed method in proper perspective.

Hydrologic Variability Considerations

The problem of designing optimal waste disposal systems in conjunction with overall basin planning gains in complexity when hydrologic variability is explicitly considered.^{1/} The concentration of most pollutants in stream waters is inversely related to the rate of flow. Consequently, a problem arises concerning the selection of the critical flow against which protection is to be sought. The problem is similar to the one encountered in selecting design flows for flood control structures except that the focus is on low rather than high flows. In other words, protection against pollution damages during the lowest flow imaginable would be analagous to protection against the "maximum probable floods."

Protection against minimum low flows is not generally considered feasible so usually a lesser goal for system design is chosen arbitrarily. A conventional rule-of-thumb standard is a mean 7-day low-flow with a probability of recurrence of once in 10 years. In practice, this means that some chosen parameter of pollution, say dissolved oxygen, is not to drop

^{1/}For a detailed discussion of this problem refer to: Allen V. Kneese, Water Pollution - Economic Aspects and Research Needs, Water Resources Program, Resources For The Future, Inc., to be published.

below a specified level such as 4 parts per million at any flows equal to or in excess to that indicated.

The use of a single rule-of-thumb standard, however, does not lend itself to designing optimum water quality management systems. This results from the fact that the flow output and range in flow of the system in any given time period is unpredictable in a strict sense. The nature of hydrological variation dictates that such predictions must necessarily be probabilistic rather than determinate (i.e. it is a stochastic variable). From this we can infer then that a given standard (say, the conventional mean 7-day flow with a probability of occurrence once in 10 years), may be applicable to one stream yet wholly unsatisfactory for others. Some means must be devised, therefore, for designing the system for the expected hydrologic variation in each case. One possible approach is by running an actual or synthetic hydrological record for a given stream through a mathematical simulation model which would register the economic losses and gains from alternative systems in response to variations in flow.

The choice of design flow is quite important in practical situations because it directly affects the degree of pollution damages against which protection is provided. In principle, the choice of optimum protection levels is an economic problem symmetrical to the choice of the size of flood against which damages are to be sought. This involves "enlarging" the degree of protection until the marginal cost of a further increment of protection exceeds the mathematical expectation of damages avoided with the cost of protection including, of course, the value of other project purposes foregone.

The principle is valid and would be rather straightforwardly applicable if the probable costs imposed by pollution could reasonably be integrated into

a single monetary measure of value. The difficulty of arriving at such a measure for a vast complex of things including equipment damage, increased treatment cost, recreational and other opportunities foregone, environmental deterioration, and the like, is exceedingly difficult under currently accepted benefit-cost procedures.

Benefit-Cost Determination Considerations for Water
Quality Project Increments

Pollution involves significant effects which are not measurable by market prices or market imputed values. Strictly speaking, this means that conventional market cost concepts are not sufficient to meet the objective of minimizing the social costs associated with waste disposal. Accurate determination of the effects of recreational benefits attributable to water quality management serves as a prime example of the complexities involved. Also, we can assume that a polluted body of water to which the public is exposed causes some unmeasured degree of damage to public character. The often overexaggerated reference to George Washington's River - the Potomac - as an open sewer, is an example of character damage recognition as a result of pollution effects.

No private market will develop for ameliorative measures for the cases cited above because an individual who provides relief for himself will automatically provide it for others as well. Consequently, private preferences will not be revealed and therefore the environmental improvement values of quality improvement measures are not inferrable from actions of a free market mechanism.

The public health aspects of water pollution present additional difficulties for evaluation. To the extent that communicable diseases are at issue, a type of interdependence in consumption exists not unlike that which water pollution causes between producers. Since some of the benefits

attained when an individual avoids a communicable disease accrue to the community at large, a community may set standards for public health that are higher than that which would be set collectively by the individuals involved. Thus in essence, a community often overrides the market's verdict, so to speak, and sets a higher standard of health. It represents the public's willingness, as a group, to accept and pay for something which they would not all pay for to the same degree unless this constraint--a desired "higher than possibly required" health standard--were so stated and as a result they could be assured everyone would comply. Consideration of politically determined constraints in the process of water resources system design can serve as a representation of social value where market valuation fails. However, the determination of appropriate constraint levels remains a critical item in the process.

Application of the Constrained Objective Function Concept
To Water Quality Management Planning

Water quality promises to become a progressively more important variable in system design and evaluation. Consequently, the evaluation difficulties presented by it are a matter of grave concern. A means must be found whereby the social value of its components including recreational opportunities, environmental benefits, social public health values, and others are reflected in efficiently designed systems. It is imperative to the success of water quality management efforts that this be accomplished even though we recognize that no satisfactory direct means for gaging relative individual preferences by means of conventional market values exists.

Let us look for a minute at how these kinds of considerations have conventionally been taken into account. Ordinarily, project results of this general character have been labeled intangibles and more or less

disregarded in the initial planning processes. Then, after such system designs have been considered ready for public consideration, has side information on these items been provided in the hope that its inclusion would have an effect on decision maker's response to the suggested plan. With the exception of one item in this vast "no man's land" of intangibles--the concern for possible loss of human life as reflected in flood control considerations--the general impact of this approach has been less successful than we would desire.

An alternative approach, and one more likely to yield a more nearly optimum system, is to incorporate constraints on the objective function into the planning process.^{1/} That is to say, let us initially and explicitly include a judgment of nonmarket derived goals into the process of system design. This can be done by treating these goals, expressed in physical terms, as limitations upon the overall objective and then proceeding to devise a system which meets the objective to the fullest extent possible, given the constraints. For example, a system which minimizes all market-type costs associated with waste disposal given the constraint that a certain level of dissolved oxygen be maintained in a stream is a case in point.

^{1/}I hasten to insert here that I do not claim paternity for this brain-child as it applies to water quality problems, although I do confess assisting in bringing it through a critical incubation period. (Rigid adherence to conventional benefit-cost analysis techniques by Federal agencies in the water resource field implies that this off-spring may have been born prematurely). A list of persons who consciously or unconsciously have helped to develop the application of the concept to water quality evaluation would include Dr. Allen Kneese, Resources For The Future, Inc.; Mr. Melvin E. Scheidt, Public Health Service, U. S. Department of Health, Education, and Welfare; Secretary Maurice K. Goddard, Department of Forests and Waters, Commonwealth of Pennsylvania; and many others.

To a degree, the constrained objective function has already been incorporated into public planning for resource development. Secretary Maurice Goddard, of the Pennsylvania Department of Forests and Waters, for example, is vigorously applying this concept in the recreational development activities of his agency. In speaking of this development program, he states:^{1/}

"In Pennsylvania we have been following a park expansion policy for the last five years summarized in our popular slogan that our goal is to build a State Park within 25 miles of every Pennsylvanian.

"In general, the kind of State Parks we are building today are not quite the same as those constructed by the state in the past. Previously, park areas were set aside in scenic areas of the State Forests. . . . Inevitably such parks were located in the least accessible parts of the Commonwealth, far from our urban population. Today, our concept of State Parks is far different."

The goal of Pennsylvania's park building program is to provide adequate outdoor recreational facilities for its rapidly expanding population, which presumably adheres to an overall objective of cost minimization. The 25-mile distance limit, however, serves as a constraint on this overall objective. Intuitively, one can hypothesize that a park system accommodating Pennsylvania's population could be developed at less cost by developing a few large parks on less valuable land than is now being utilized. It was suspected by planning authority, however, that the people of the state valued ready access to the facilities, as provided by the 25-mile distance limit constraint, to be at least worth the extra cost of the park system that would result from the development of numerous smaller sized units throughout the state. The tremendous support given to this effort by the state population provides ample evidence that this planning hypothesis was correct. This

^{1/} Maurice K. Goddard, "Recreation Aspects of River Basin Development," Cooperative Planning for the Shenandoah Valley, Interstate Commission on The Potomac River Basin, Washington, D.C., June 1960. p. 28.

serves as a prime example of the constrained objective function applied in an actual planning situation.

Let us investigate briefly how this principle could be applied to water quality management planning. Planning of an optimal waste-disposal system, as a subsystem of an overall plan for maximizing net benefits from a water resource development project, will be used as an example. Certain development goals are recognized initially and treated as constraints upon the cost minimization objective. Let us consider, in this case, that social choice has dictated that all streams in the study area must under specified frequency conditions contain a specified minimum amount of dissolved oxygen. This perhaps would be translated into a design flow standard of a 10-day low flow with a probability of recurrence once in 15 years. The dissolved oxygen level could conceivably be set at a minimum standard of 4.5 p.p.m. at any flows equal to or in excess of that indicated.

A system would subsequently be designed which would minimize the costs associated with waste disposal, subject to the constraint that the indicated D.O. is to be maintained. Conceivably this would require a very different combination of units, with differing operating procedures, than an alternative design system for this same study area developed without this constraint. Furthermore, presuming the constraint is effective, it would result in a higher cost system than could otherwise have been achieved. The extra cost represents the limitation which the constraint places upon the objective.

The distinction between objectives and constraints can be somewhat troublesome when "policy" constraints are involved. "Technological" constraints, however, are relatively clearcut in that they merely set the physical framework within which the evaluation procedure is carried out.

The following distinction between objectives and constraints has been proposed: "A practicable distinction between constraints and objectives might go as follows: A requirement is a constraint if (a) it must not be violated at any cost however high or with any probability however low, and (b) if there is no gain or advantage in fulfilling it. On the other hand, a requirement is one of the objectives of the firm if it can be violated, though at a cost or penalty, or if there is an advantage in overfulfilling it."^{1/}

Policy type constraints often do not fully meet the rigorous conditions prescribed in the above example. Certainly many constraints that would be involved in pollution abatement problems would have difficulty doing so. This points out the great importance of not considering constraints immutable and the need of testing the sensitivity of costs to them.

It suggests also that this observation has a bearing on our overall approach to comprehensive planning. It suggests implicitly that we need to look at a number of alternative approaches to a problem rather than proceeding to a single solution carefully prescribed by a given set of rule-of-thumb standards, or if you will, by a given set of constraints. One way of looking at alternative approaches to a problem solution in this case would be to test the cost sensitivity of selected constraints.

By varying a constraint by small amounts, redetermining the optimum system in each case, and collating the change in costs with the associated physical changes, i.e. effects on oxygen levels, appearance, aquatic life, and the like, information can be provided which permits considered choice among given alternative plans presented to the public (or its elected

^{1/}Robert Dorfman, "Operations Research," American Economic Review, September 1960. pp. 614-615.

representatives). This provides one means of exploring a collective demand function reflecting the distribution of political power, thus permitting a closer approach to meeting the collective preferences of society.

Would such an approach be compatible with existing benefit-cost analysis procedures in use by Federal agencies? On first glance, it apparently would not be compatible. I feel, however, that this concept can be sufficiently modified to allow fitting it into the existing system of benefit-cost analysis. This would require stating the results of varying the constraint level in terms of what they must "at least be worth". This would apply only in those cases where the constraints are not commensurable with the project objective, i.e. not valued directly or imputable from the market. If, for example, a social judgment were to be made that algae growth is to be restricted beyond the point indicated by the cost minimizing solution, it would, of course, not be possible to say precisely what the avoided destruction (real cost) of the resulting aesthetic pleasure is worth. By comparing the optimum system with and without the constraint, however, it would be possible to indicate to the public representatives what the least value is that must be attached in order to make the level of control procedures worthwhile.

If on the basis of this analysis, it was decided that this goal was nonetheless desired, (a situation analogous to assuming that loss of human life must be avoided in a flood control project), then it would be incorporated into the overall benefit-cost analysis at a minimum of 1:1 ratio. In the case of a multipurpose storage project, such an analysis of low flow augmentation requirements would have to be considered a suboptimum

of the full system.^{1/} Once accepted, however, it would in turn place an effective constraint on the other project purposes. It would explicitly require that storage allocation required to meet the low flow augmentation constraint would have to be achieved first and optimum allocation of remaining project purposes would have to proceed within this limitation. Whether or not this can be accepted is a policy question and beyond the purpose of this paper. The intent here is only to show how it might conceivably be developed.

Summary and Conclusions

This paper was not designed to provide a "cookbook approach" for comprehensive water quality management planning efforts. Rather, it provides a way of thinking about the objectives of such planning efforts and to suggest a possible way in which some heretofore intangible benefits associated with such project increments may be given adequate consideration in comprehensive river basin planning efforts.

Inherent in the paper are a number of concepts and ideas that as yet are not fully understood (or perhaps appreciated is a better word) by many professional engineers and administrators engaged in the development of comprehensive water development and pollution control programs.

Among the more significant of these are:

1. The economist can play a dual role in comprehensive planning efforts. First he can provide a certain portion of the basic data requirements through the development of an economic base study of the Project

^{1/} For an instructive discussion of optima and suboptima, see C. J. Hitch and R. N. McKean, The Economics of Defense in the Nuclear Age, (Harvard University Press, 1960). For a discussion more directly addressing water resource issues, see R. N. McKean, Efficiency in Government Through Systems Analysis, (New York: John Wiley and Sons, 1958.)

area. Second, he can introduce a means of analysis into the planning process which explicitly introduces the valuations of the public into the process of designing optimum systems.

2. The quality and quantity aspects of the water resource cannot be artificially separated when planning for optimum development of water quality management project increments. This implies therefore that evaluation of these increments cannot be accomplished without simultaneous consideration of other project purposes involved in multipurpose, multiunit project planning efforts.

3. The constrained objective function type of framework is a flexible tool and potentially useful for comprehending development goals not strictly commensurate with those derived from market valuation. The inclusion of this function into the planning process, however, means that the procedure can not lead directly to a full optimum system. It would have to be considered a suboptimum, or if you will, a provisional optimum subject to higher level decisions constraining the minimization-maximization process. From the point of view of achieving maximum efficiency in system design, this requires that policy constraints should be considered "provisional." They would be viewed, therefore, as a subject matter for further research and study with the intent of expanding their meaning with respect to preferences of society.